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A NETWORK-BASED GIS FOR SUPPORT OF RAPID RESPONSE ENVIRONMENTAL ASSESSMENT.

Farid Askari[1]*and Erick Malaret[2]
[1] Naval Research Laboratory, Washington, D.C. 20375
Currently at
*SACLANT Undersea Research Centre
Email: askari@saclantc.nato.int

[2] ACT Corp, Herndon, VA, USA
Email: malaret@actgate.com

Abstract

An operational Rapid Environmental Assessment (REA) system requires timely access to geospatial information from multiple sensors and platforms. We describe an interactive network-based near-real-time image processing system that relies on high speed access to remotely stored data and processing power. The oceanographic and atmospheric applications of spaceborne synthetic aperture radar (SAR), and the various algorithms that are under development for extracting geophysical products from the imager will also be discussed briefly.

1. Background

This article presents an overview of a network-based Geographic Information System (GIS) architecture and its applications that is currently under development for support of NATO's rapid environmental assessment efforts. The objective is to demonstrate near real-time image processing capabilities, and interactive exchange of data between multiple, distributed users.

To address one of the central objectives of Rapid Response (RR) which is the dissemination of time-critical data and information, we have implemented an interactive network-based image processing system that relies on high speed access to remotely stored data and processing power.

The types of satellite data collected during RR-96 included: ERS-2 and RADARSAT synthetic aperture radar (SAR), NOAA Advanced Very High Resolution Radiometer (AVHRR), DMSP special sensor microwave imager (SSM/I) and the French SPOT multi-spectral imagery. The core of the remote sensing data for RR-96, however, consisted of AVHRR and ERS-2/SAR imagery. RADARSAT imagery, however, was not utilized during the experiment due to delays in receiving the data.

In support of RR-96, a total of 40 ERS-2 and one RADARSAT SAR images were acquired during the period August 12 to 5 October, 1996. The raw SAR data stream was first down-linked in real-time to the receiving station in West Freugh in UK. From there, the data was routed via high speed links to DRA Farnborough remote sensing facilities for image formation. Then, high resolution (150m) SAR images were sent via the INTERNET to Naval Research Laboratory (NRL) in Washington, D.C. for post-processing and image interpretation. Finally, the annotated feature maps were sent via the INTERNET from NRL to the SACLANTCEN World Wide Web (WWW) homepage. The approach used during the exercise by the image analyst was to view the low resolution (1.5 km) imagery, select regions and features of interest, and post the final products on the home page for the operator. While this approach served the demonstration purpose of the RR-96 which was the dissemination of data over the WWW, it severely restricted the end-user from interacting with the data or from choosing his/her own regions of interest. Thus it became clear that a new approach for information extraction was needed in order to realize the full benefits of high speed networking and to transform RR from a experimental concept to operational status.

In this initial phase, for demonstration purposes, we use only the ERS-2/SAR imagery, which because of it's high spatial resolution, is by far the most computationally demanding sensor, requiring massive amounts of storage, network throughput and processing power. A separate GIS module for multi-layered data integration and sensor fusion has been developed which uses a "hypercube" architecture (Figure 1), the details of which are given in [1].
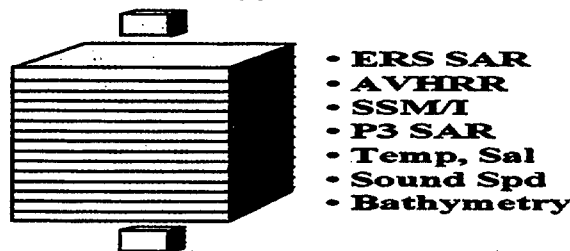

Figure (1) Multi-layered geo-referenced data

- ERS SAR
- AVHRR
- SSM/I
- P3 SAR
- Temp, Sal
- Sound Spd
- Bathymetry

Here, we focus on the networked-based image browser that was developed for the ERS-2/SAR system.

2. The Architecture

The basic components of the architecture consist of

the image server (IS) system, the network, and the applications and tools for the client (Figure 2). It is assumed that all clients have access to the IS via a modem (14.4 kb/s) or a high speed network, and interact with the host using a WEB browser. Once connection is established with the server, two possible scenarios exist. In the first scenario it is assumed that client A has limited computing power in terms of speed, memory, and storage. In this case we have configured a system in which the data, the computing power, and algorithms all reside on the host/server side. The data sets and client/applications are not collocated. The satellite imagery is located and stored remotely on the server, and is supplied to the client/application on as needed basis by means of a modem or high speed-network. In the second scenario, client B has significantly more computing power allowing downloading and use of locally resident processing tools.

In the operational environment, the first scenario is more likely to occur. As most field operators do not have access to high speed computing or large storage devices, it is often impractical to transfer large volumes of data. For example, the SAR data storage requirements collected during RR-96 exceeded 5 GB of disk space. The other consideration is that there may be multiple sources of data which may need maintenance and updates. These tasks are typically performed at a fusion center and should not involve or put unnecessary burdens on the client. Given these constraints, an innovative approach to distributed computing is required in order to provide the user with maximum flexibility and interactions.

2.1. Hardware/software Configuration

The IS system which stores, retrieves, and processes the client-supplied queries consists of the following hardware and software components:
  〈   200 MHz Pentium Pro operating with single or multiple processors.
  〈   ProView image processing software and ProViewWeb server.
  〈   CD-ROM jukebox.
  〈   Two 9 GB hard drives.

The IS may consist of a single Pentium Pro machine with one or multiple processors, or a series of coordinated platforms operating in parallel. The main engines for image processing and hyper text markup language (HTML) file generation are the ProView and ProViewWeb software systems. All the applications, including sensor fusion, multi-layered data synergism, automatic feature detection, and extraction of geophysical parameters from remotely sensed imagery were developed using ProView and ProViewWeb which are available commercially. These are highly versatile, PC-based languages (developed by ACT), that operate under the MS Windows 3x and NT, as 32 bit application. One of the unique capabilities of ProView is that it permits the processing of large volumes of data using virtual image variable, that is, images can be large as the disk space.

Also ProViewWeb allows for interactive image processing, user defined products, visualization, data queries, and HTML file generation
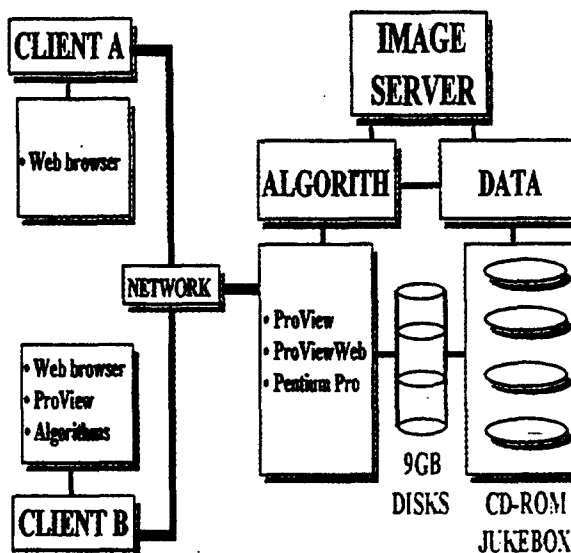

Figure (2) The system architecture

On the server side, SAR data is organized in three layers and in two different spatial resolutions. In the first layer, the data is organized as a series of mosaics covering the RR operating areas (Figure 3).
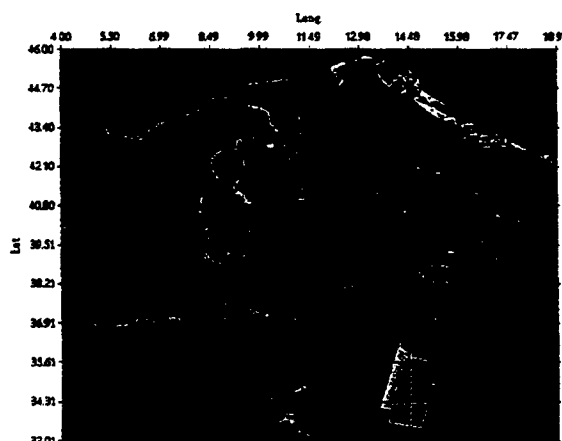

Figure (6) Edge-enhanced image

In this layer, the client can choose imagery by date, by geographic coordinates, or by specifying the satellite orbit number. In the second layer, the client can access low resolution (1.5 km) SAR maps that are georeferenced and are individually stored on SCSI disks. The low resolution images (Figure 4) provide a synoptic view of the regions and features of interest
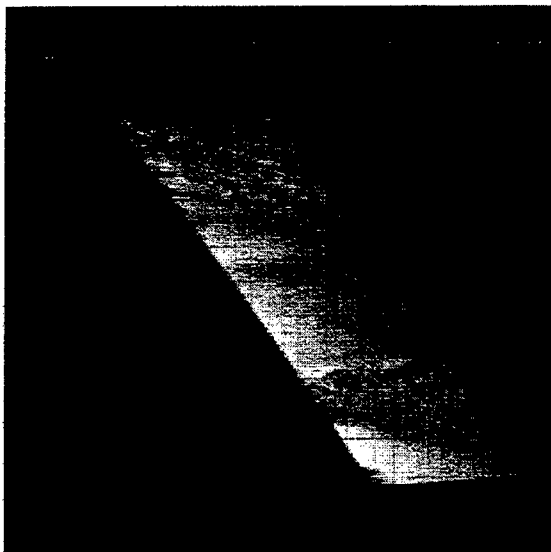
2.2. Algorithms

Improvements in satellite technology have significantly affected our ability to assess the environment. At the same time, however, the complexities and the volume of information that can be processed by human interpreters have dramatically increased. To tackle this complex, multidimensional problem some degree of automation is required. Here we have designed a series of algorithms to assist in extracting quantitative information.

⟨ Edge detection.
⟨ Two-dimensional directional spectra.
⟨ Cluster seeking.
⟨ Wind vector retrieval.
⟨ Sensor fusion.
⟨ Automatic shape detection.

Figure 6 is a result of applying a edge-detection filter to the previous image (figure 5).

Figure (4) Low resolution synoptic SAR image. ESA/Copyright

In the third layer, the client specifies a sub-region (512x512) of his choice which is located within the low resolution image. At this point the IS retrieves high resolution (150 m) image subsets from a CD-ROM jukebox. Figure 5 is an example of a sub-region from the southern tip of Sicily. If the clients have the computing capabilities they can download raw data and proceed with their own applications. However, if there are minimal computing capabilities, clients can utilize the remote image processing power that resides on the server side. For both cases, several image processing algorithms have been developed for the client
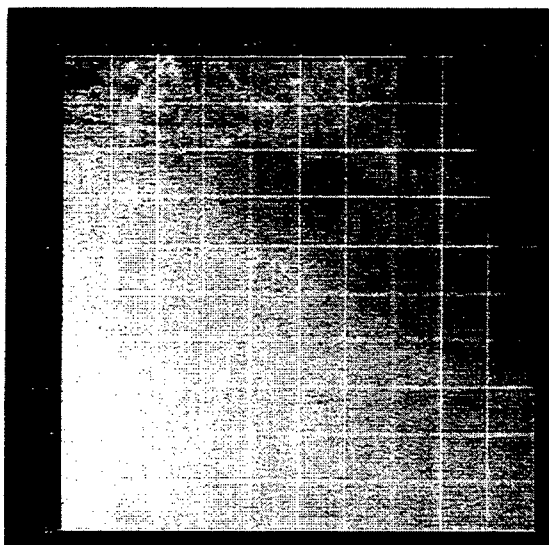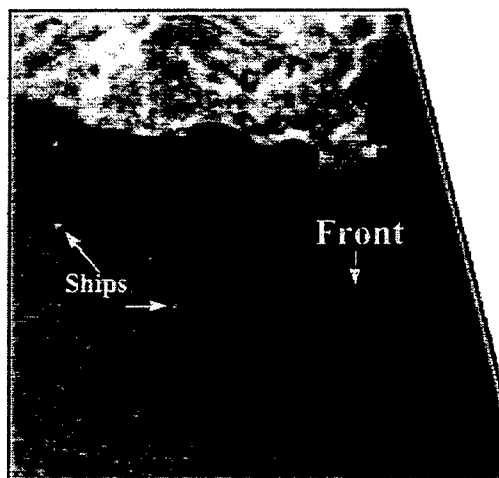

Figure (5) High resolution sub-mage ESA/Copyright

Figure (6) Edge-enhanced image

3. Applications

SAR imagery can provide rapid assessment of the background oceanographic and atmospheric environment over a variety of spatial and temporal scales. Because of its high spatial resolution and all-weather capabilities, SAR can also detect manmade features such as oil spills and ships/wakes. Below is a partial list of oceanographic and atmospheric features that are readily identifiable in SAR imagery [2]:

⟨ Internal and surface waves.
⟨ Current boundaries and types.
⟨ Fronts and eddies.
⟨ Bottom signatures.
⟨ Wind/Gust fronts.
⟨ Atmospheric internal gravity waves.
⟨ Katabatic winds.
⟨ Cellular convection cells.
Thunderstorms, rain cells, and squall lines.

For tactical applications, however, one must go beyond simple feature identifications and detection. The goal is to derive as much quantitative information and geophysical products from a combination of sensors as possible given the spatial, spectral, and temporal constraints of the sensors. Some of the SAR-derived geophysical products include: locations and types of oceanic/atmospheric fronts, wind speed and direction, propagation direction and height of shoaling waves, magnitudes of littoral currents, and locations of coastal geomorphological features such as submarine sand waves and sand banks, beach berms and troughs, submarine canyons and headlands. More importantly, subsequent to detection and identification, the characteristic time scales for the various physical processes must be defined. The ultimate goal is to provide the end-user with information within tactically usable time scales. The usable-time-scale is, however, a function of two temporal variables; the "delivery-time" through the network, and the "age" or "life-span" of the physical processes. The "delivery-time" can vary for each client depending on the system's communication bandwidth and throughput requirements. Assuming that an atmospheric gust front and an oceanic front have been identified in a SAR image. We know from dynamical principals that atmospheric gust fronts can form and dissipate over periods of several minutes, while oceanographic fronts can last over periods of several days. Operationally, it takes about four to five hours from the time of down-link to digitally process a SAR image. Hence, from the standpoint of the end-user, information regarding the gust front may be tactically useless, while the information regarding the oceanic front remains tactically useful. A strategy for defining the "life-span" or "age" of the features seen in the imagery must be devised in accordance with physically-derived scaling parameters [3].

4. Conclusions

With the recent advances in high-speed networking technology, it is now possible to deliver to the end-user time-critical oceanographic/atmospheric information on a variety of spatial scales. An operational REA system requires timely access to geospatial information from a multitude of sensors and platforms. Here, we implemented the framework for a near real-time image processing architecture that allows high-speed access to information which is stored on a remote host. The challenge is to deliver to the end-user useful information faster and in a more automatic fashion using multiple distributed data sources.

5. Acknowledgments

References

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